Super-K Electronics Upgrade

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About this talk

- I am making no claim regarding electronics for the new detector.
- This is just a report of the most recent effort for a similar detector.
- Rough schedule was:

  2004 – Specification, conceptual designs

  2005 – R&D and engineering

  2006 – Prototyping and testing

  2007 – Final tests and production

  2008 – Delivery and Installation

Previous Electronics (1996-2007)

Served us well, but …
Many discrete components subject to failure.
High power consumption.
Nagging flaws desirable to correct.
Opportunity for performance improvement.
Opportunity for new DAQ architecture.

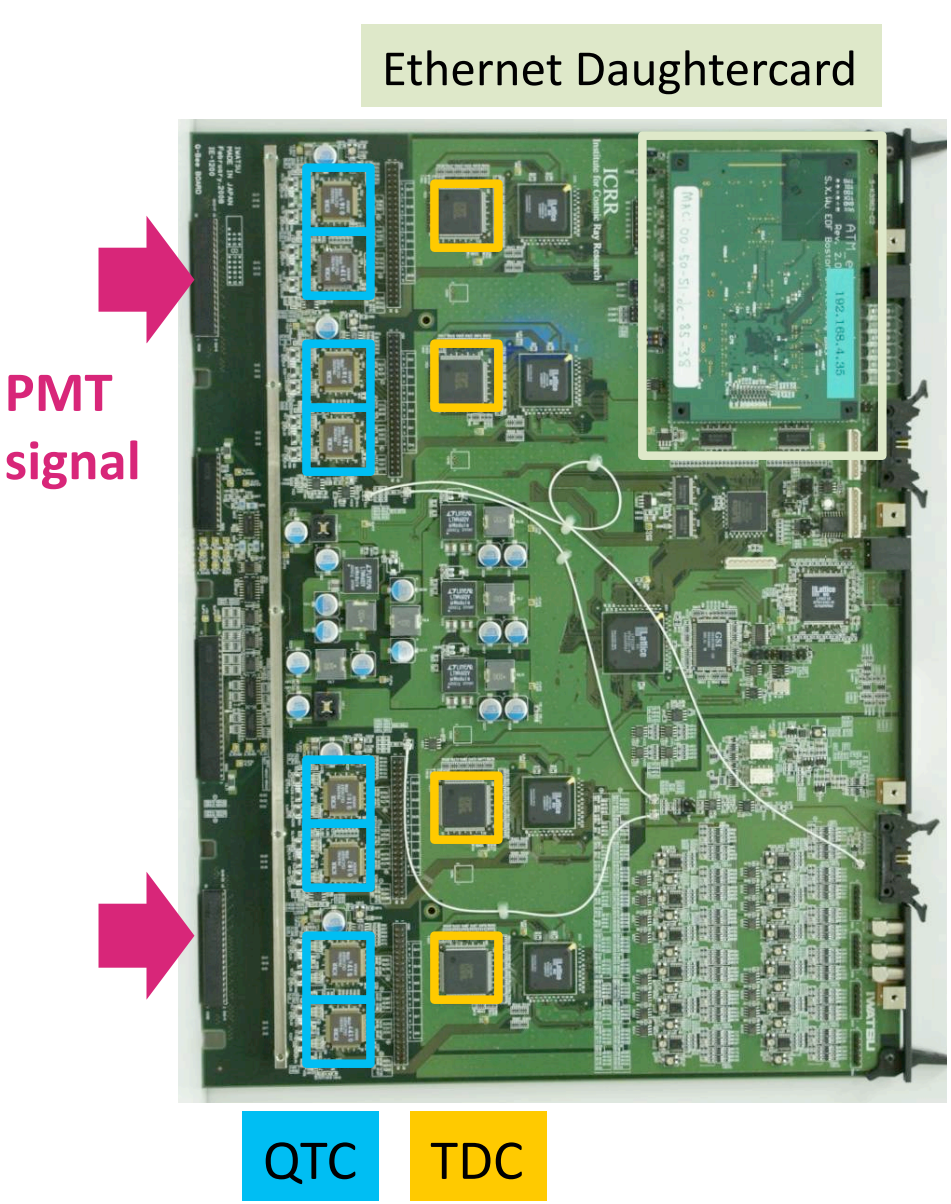
2003: Discussion started.

Plus: Outer Detector instrumented with completely different system: custom front-end plus LeCroy FASTbus TDC.
Unifying design and operation desirable.

Specifications (2004):

- Equal or exceed every spec of previous system:
- High density 12→24 ch/board
- Less deadtime 1 μs→0.4 μs (good for muon decay *e*)
- Better resolution 8→12 bit
- Wider dynamic range 250 p.e.→1000 p.e.
- Lower noise (reduce hit threshold 0.3 p.e. → 0.1 p.e.)
- Lower power consumption 4W→1W
- More highly integrated
- Keep TKO crate for power
- Ethernet readout (→20x peak data rate)

QBEE



QTC-Based Electronics with Ethernet.

comprised of:

QTC: Charge-to-Time Converter
Custom IC (ICRR/Iwatsu)

TDC: AMT3 chip (designed for Atlas)

Ethernet Daughtercard
(U.S. group)

SiTCP: Silicon TCP
Firmware implementation of TCP/IP (KEK)

Development

- QTC custom IC and QBEE module designed by Iwatsu Electric Co. in collaboration with scientists from ICRR/U. Tokyo. Development costs seem to be mainly supported by ICRR. QBEE is a quasi-commercial product – eg. RENO is using ~ 50.
- Ethernet daughtercard designed by Boston University. Detailed interface specification exchanged with Iwatsu. Successful collaboration.
- Our (U.S. SK collaborator) marginal cost was $130/ch.

QBEE(QTC Base Electronics and Ethernet)
IE-1200

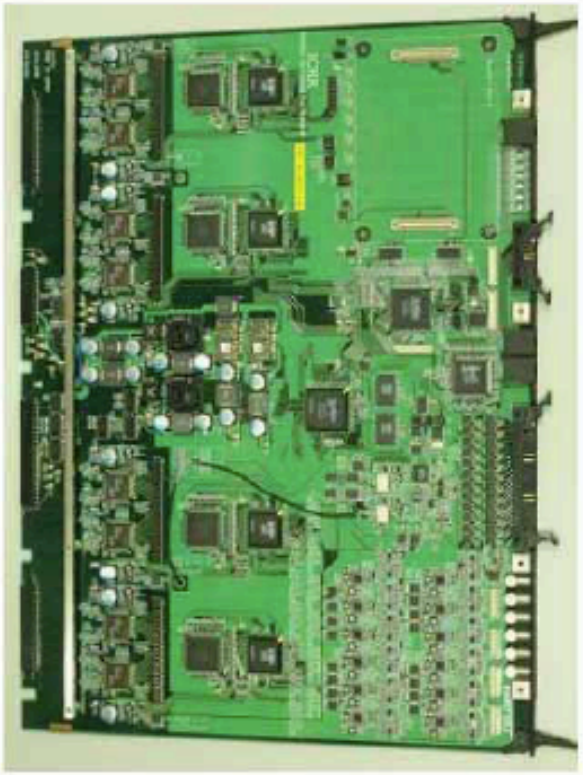


Fig. 1. Photograph of the QBEE. There are 24 input channels. It consists of 8 QTC chips and 4 AMTs.

- A QBEE board is a special board developed as electronics for Super-Kamiokande(SK).
- Eight QTC-LSI and four TDC-LSI are carried, and a QBEE board can process the signal from PMT of total 24ch.
- Each ch has a dynamic range from 0.2PCs to 2500pC(s) with three stages (Large, Medium, and Small).
- It is controllable by Ether-Net by adding Daughter-Board developed at the Boston University. When not using a Daughter board, it can control by the TKO bus.

QTC (Charge-to-Time Converter)

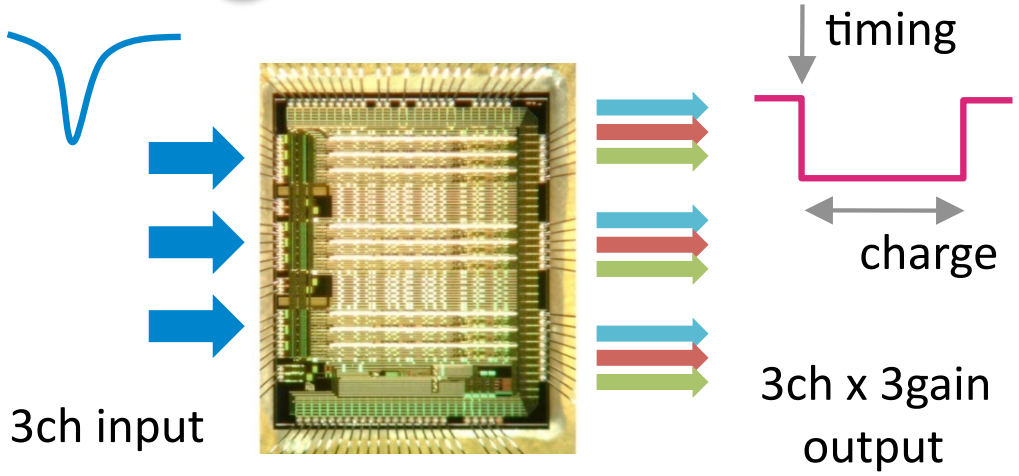


TABLE I
SPECIFICATION OF THE QTC

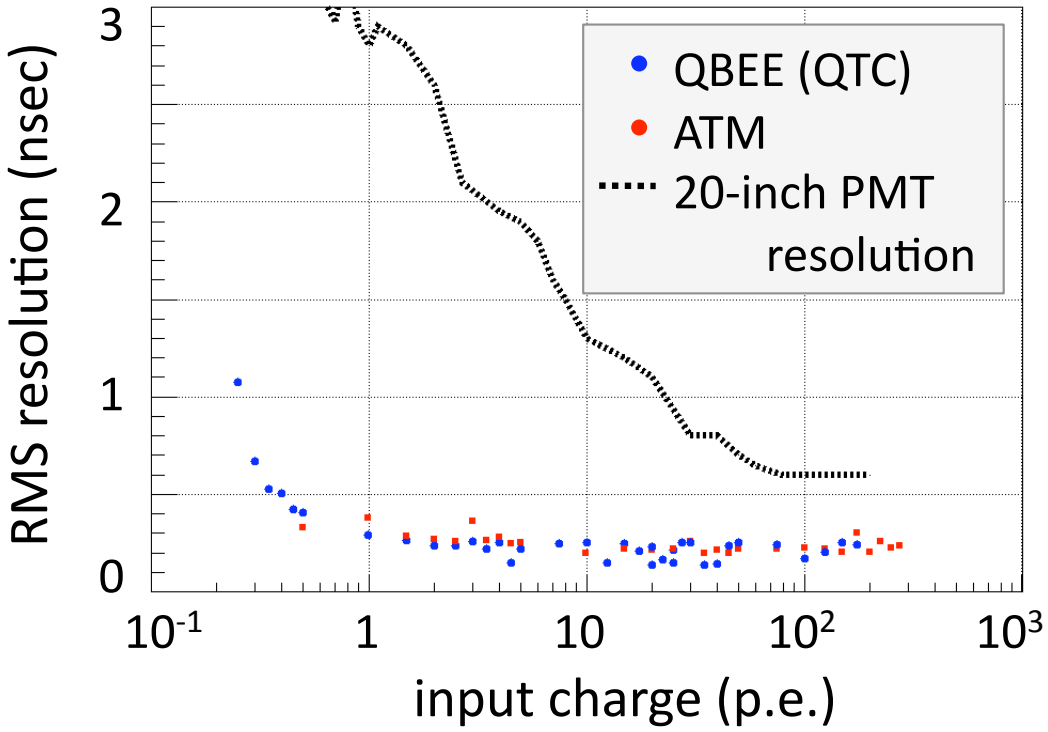
Number of Channels	3
Process Speed	~ 500 ns/hit*
Number of Gain Stages	3
Dynamic Range	0.2 ~ 2500 pC*
Charge Resolution	~ 0.1 pC* (< 50 pC)
Output Level	LVDS
Supply Voltage	+3.3 V
Power Dissipation	< 200 mW/ch
Process	0.35 μm CMOS
Package	100 pin CQFP

(* : externally adjustable)

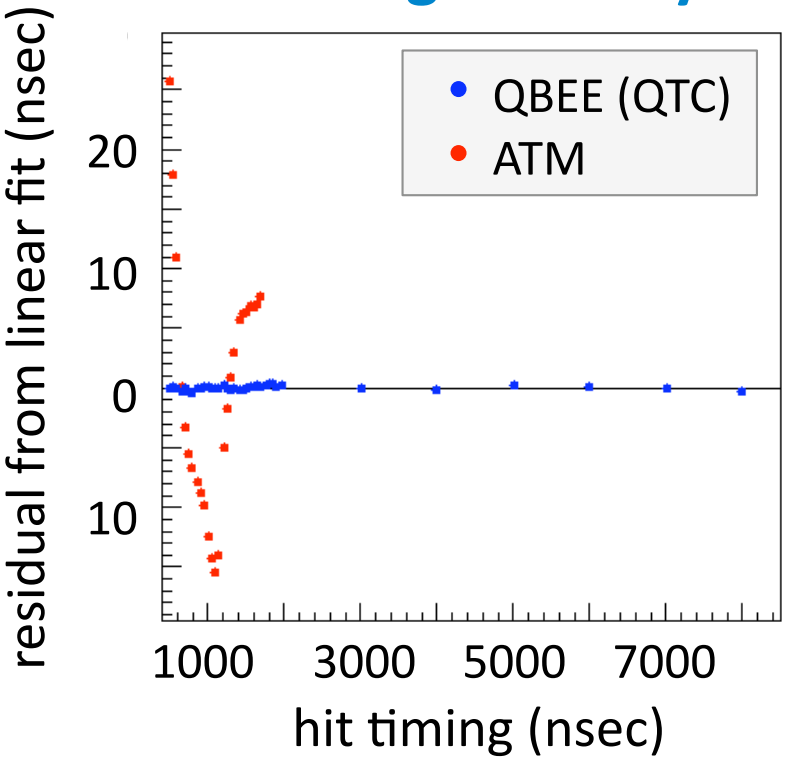
- **Built-in Discriminator**
- **Processing Speed**
  - 400 ns charge integration gate
  - ~1usec hit cycle
- **Dynamic Range**
  - 3 gain stages (1:7:49x)
  - 0.1 ~ 1250 p.e.

QBEE Performance - Timing

Timing Resolution



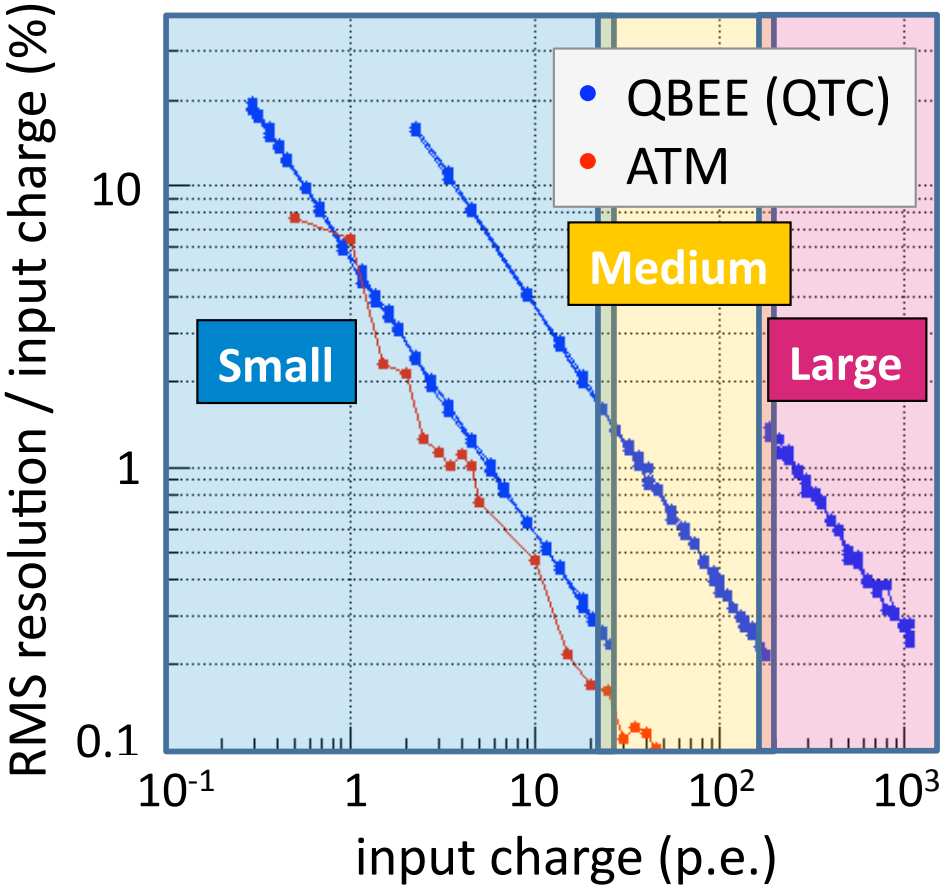
Timing Linearity



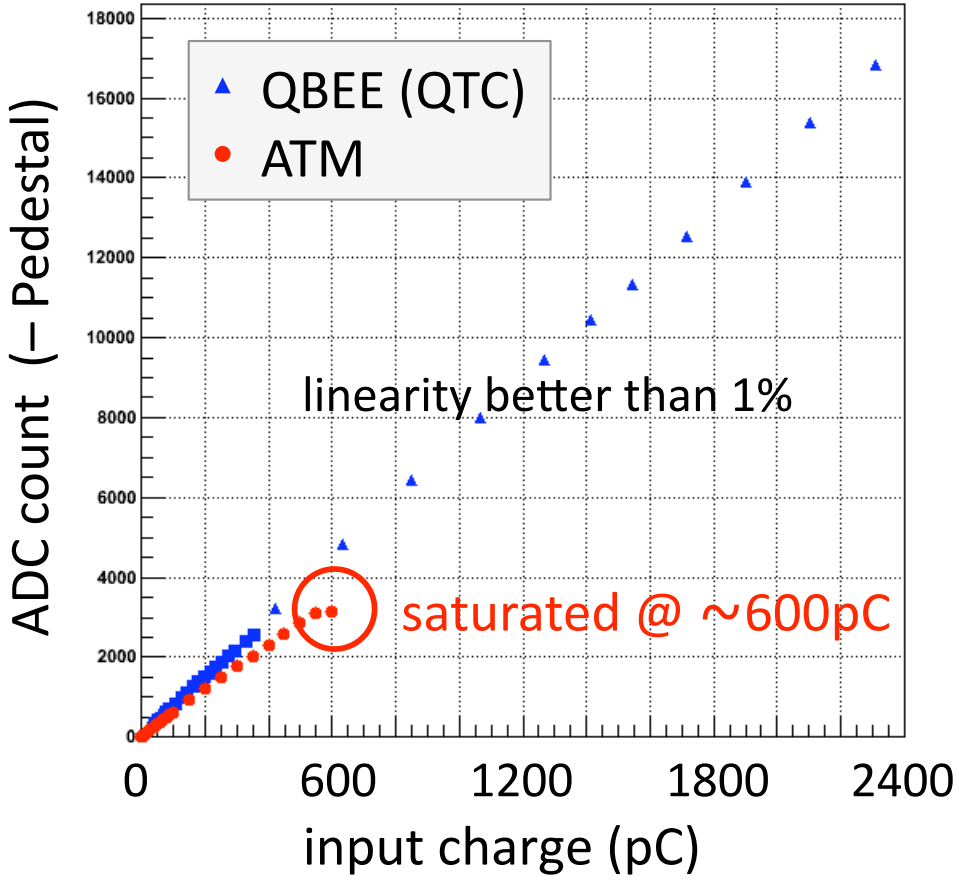
0.52 nsec / count

QBEE Performance - Charge

Charge Resolution

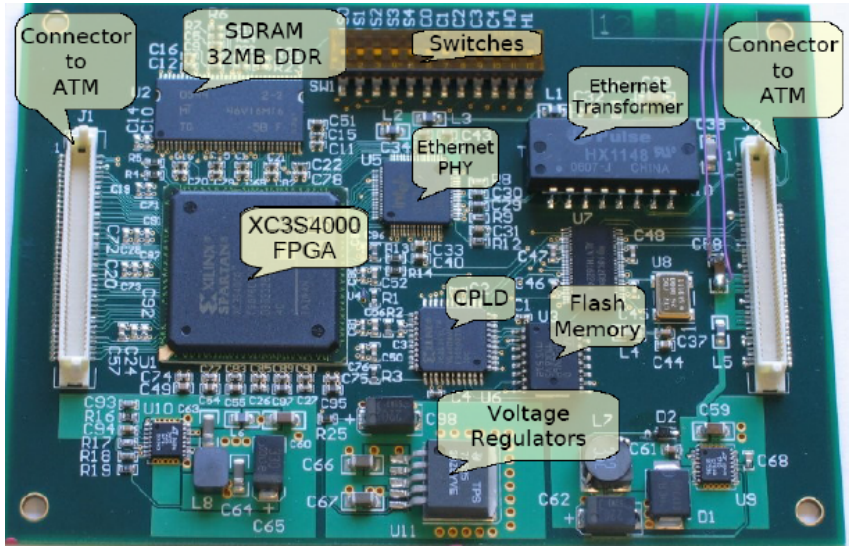


Dynamic Range



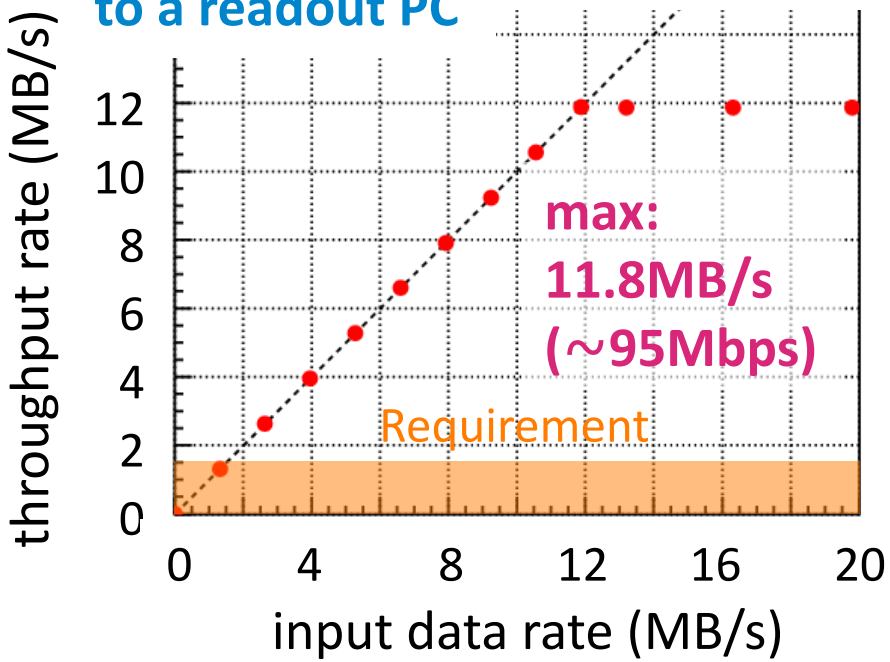
1 p.e. ≈ 2 pC

Ethernet Daughtercard + SiTCP



- 100-base T
- 32MB SDRAM
- Set IP by switches
- High speed data readout : TCP
  Control : UDP
- Keeps data transfer OFF backplane (noisy)
- Flexible DAQ architecture using commodity network switches
- Can plug into your laptop for testing!

QBEE throughput from analog input to a readout PC



Required data transfer speed :

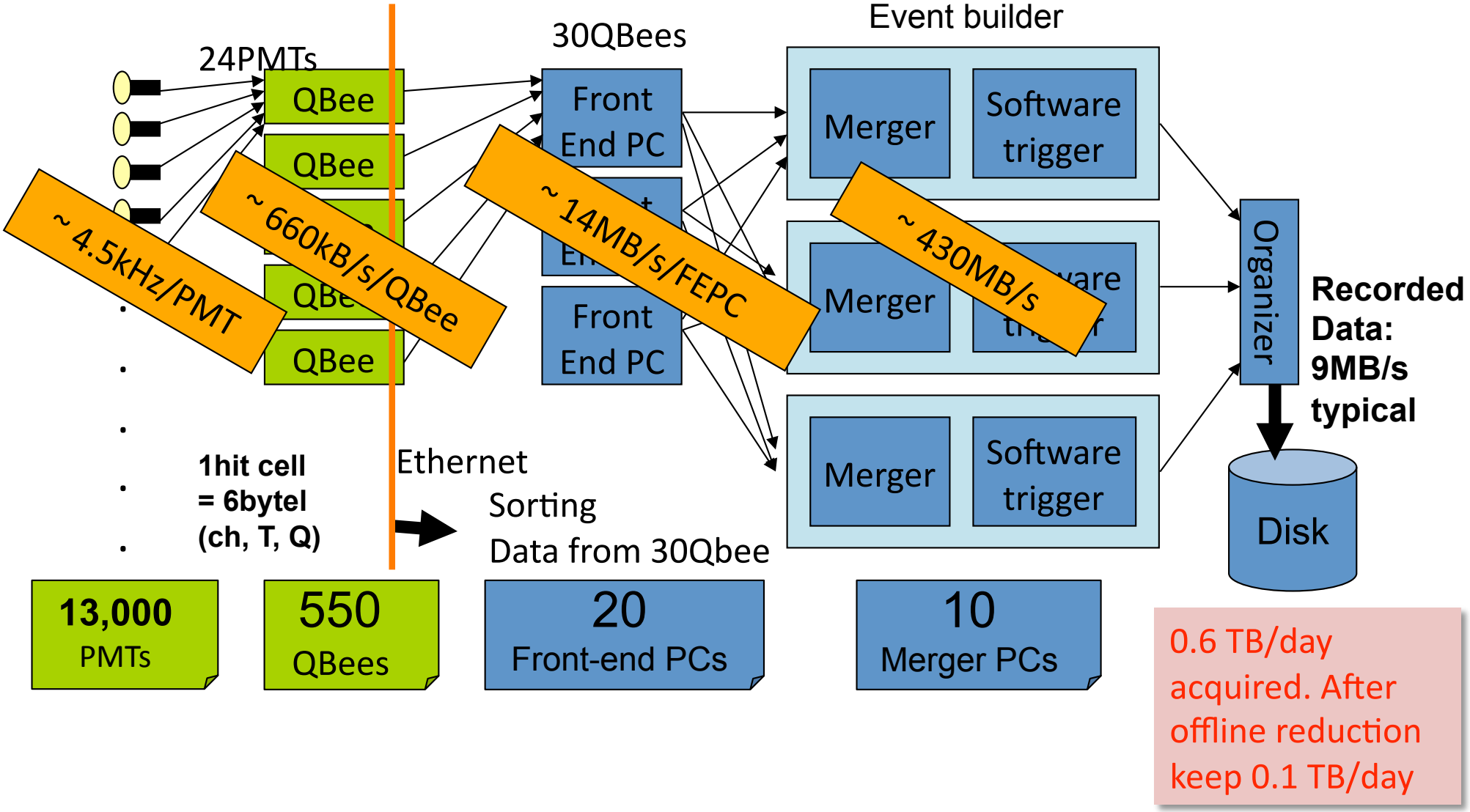
(PMT dark noise) 10kHz x 6byte x 24ch
= 1.5MB/sec/board

Installed – 9/2008

LAN cables for readout and control

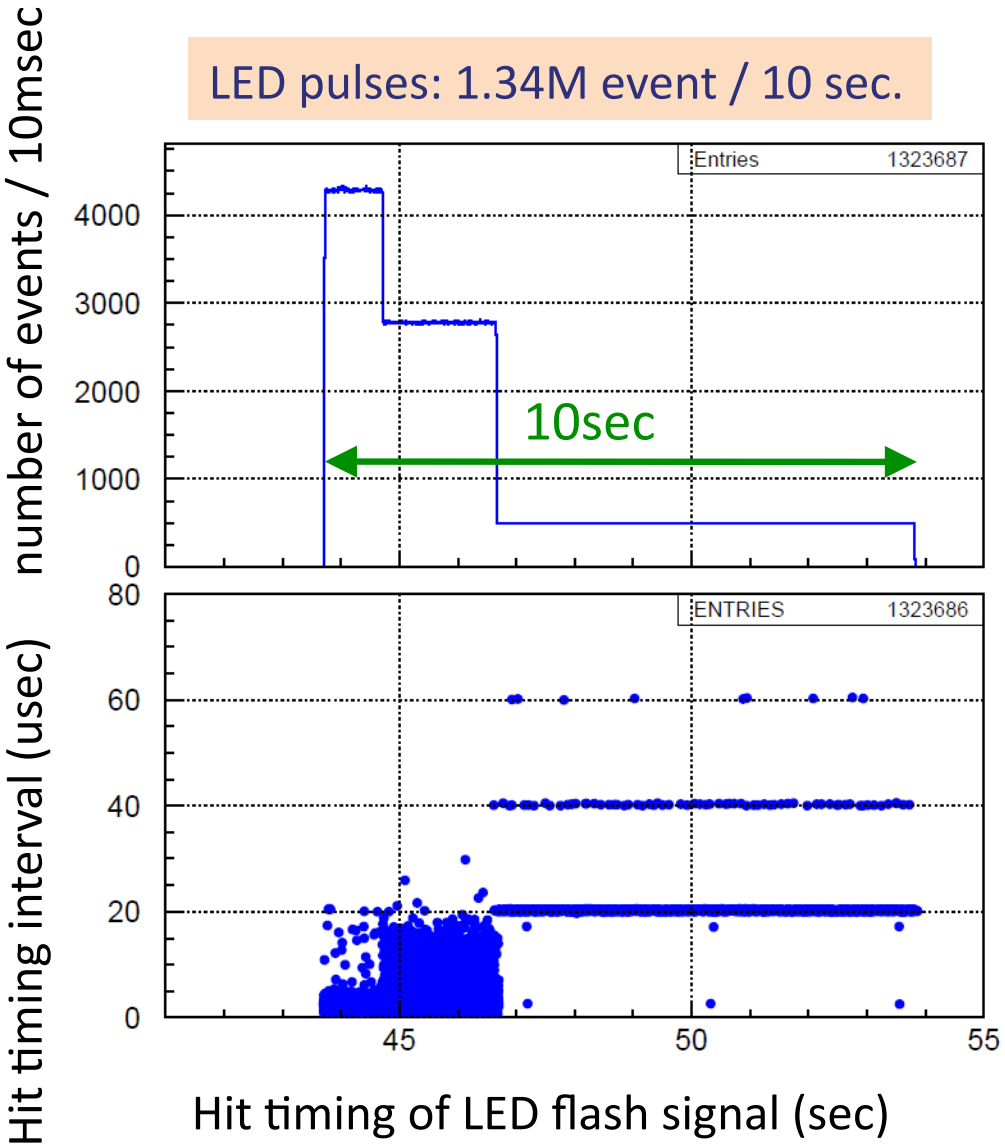
PMT cables come into the back of the TKO crates

Throughput


24PMTs
30QBees
Event builder
QBee
QBee
QBee
QBee
Front End PC
Front End PC
Merger
Software trigger
Merger
Merger
Software trigger
Organizer
~ 4.5kHz/PMT
~ 660kB/s/QBee
~ 14MB/s/FEPC
~ 430MB/s
Recorded Data: 9MB/s typical
1hit cell = 6bytel (ch, T, Q)
Ethernet
Sorting
Data from 30Qbee
Disk
13,000 PMTs
550 QBees
20 Front-end PCs
10 Merger PCs
0.6 TB/day acquired. After offline reduction keep 0.1 TB/day

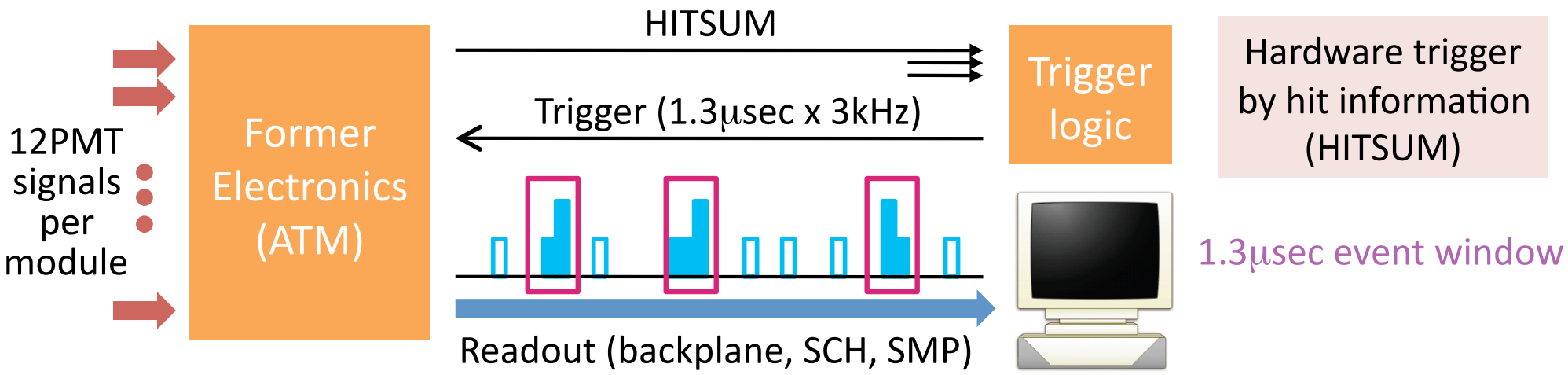
Supernova Burst Test

LED pulses: 1.34M event / 10 sec.

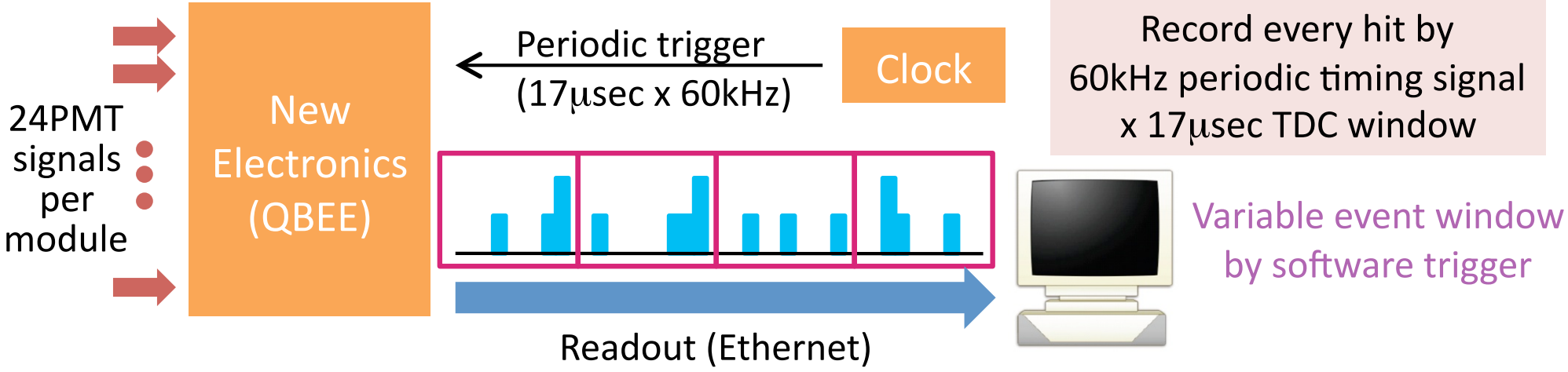


- Electronics and online DAQ ran without stopping.
- No significant dead-time even for 1M event / 10 sec burst
  - > 150 x SN in G.C.
  - > 20 x current system

Old → New:
Hardware Trigger → Record Every Hit



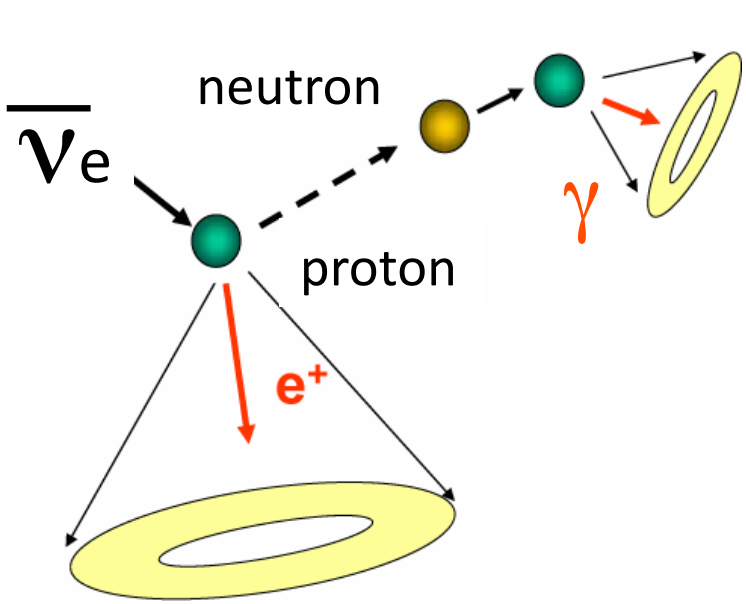
No hardware trigger. Instead record all hits and apply software triggers.

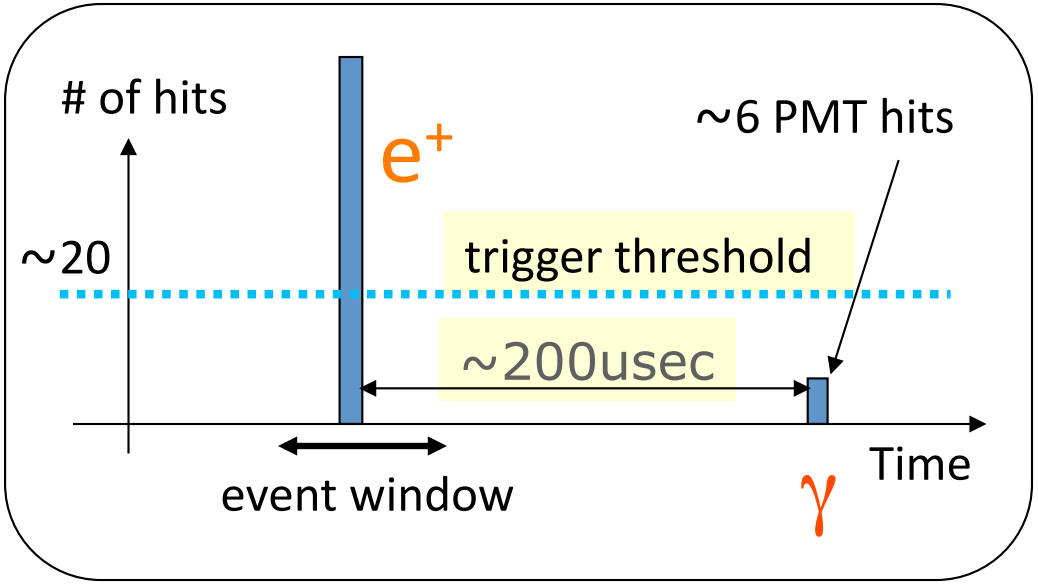


Motivation for Record-Every-Hit

Record low energy events, below hardware trigger threshold

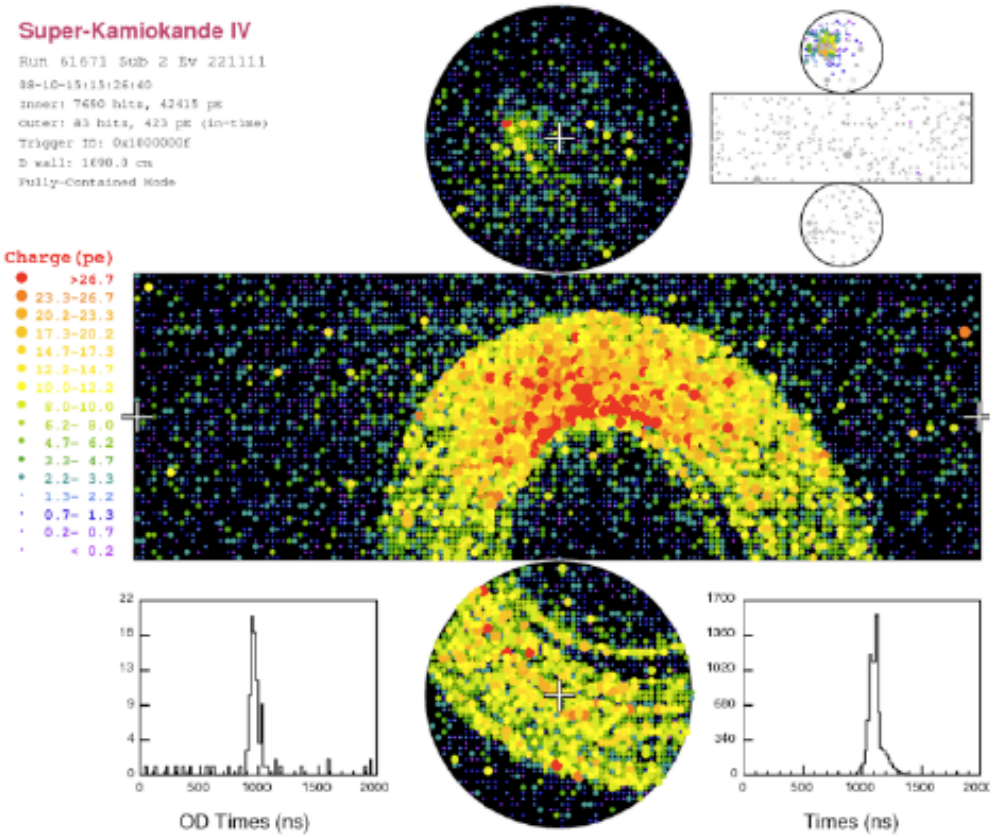
– Diffuse Supernova Neutrino Background

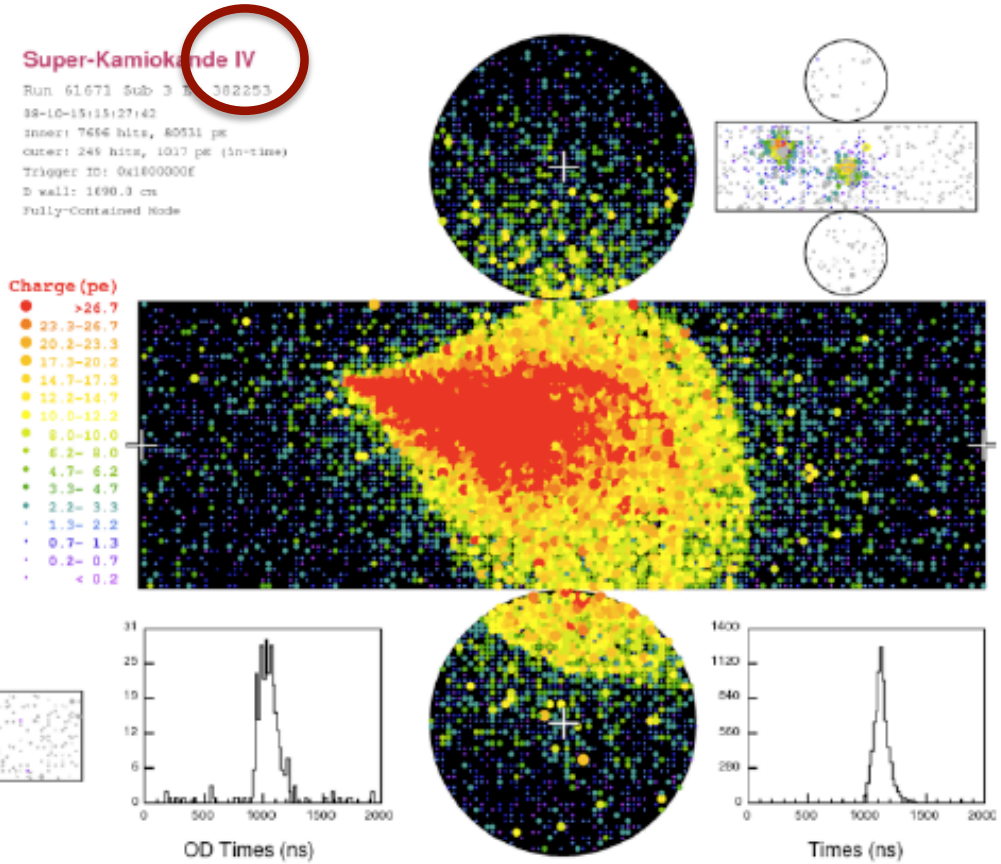




Summary

SK electronics replaced and DAQ rewritten. Concept to installation 2004-2008.
In time for T2K.





- Operational experience is good so far. We will review the first sizeable data set at the June 2009 collaboration meeting.